

TITLE OF THE INVENTION

PRINthead AND IMAGE PRINTING APPARATUS

FIELD OF THE INVENTION

5        The present invention relates to a printhead and image printing apparatus and, more particularly, to a heater driving circuit in an ink-jet printhead.

BACKGROUND OF THE INVENTION

10       One of information output apparatuses in a word processor, personal computer, facsimile apparatus, and the like is an image printing apparatus which prints desired information such as a character or image on a sheet-like printing medium such as a paper sheet or film.

15       Various methods are known as the printing method of the image printing apparatus. In recent years, an ink-jet method has particularly received a great deal of attention because the ink-jet method enables noncontact printing on a printing medium such as a paper sheet, easily achieves 20 color printing, and generates little noise. In terms of low cost and easy downsizing, the printer generally widely adopts a serial printing arrangement in which a printhead for discharging ink in accordance with desired printing information is mounted, and printing is done while the 25 printhead is reciprocally scanned in a direction perpendicular to the feed direction of a printing medium such as a paper sheet.

Fig. 12 shows a conventional heater board 1100 of a printhead which prints by bubbling and discharging ink by using heat energy.

The conventional heater board (printing element board) 1100 comprises, on a single semiconductor substrate, heater resistors 1101 serving as electrothermal transducers, high-breakdown-voltage MOS transistors 1102 which switch a current, and bit selection circuits 1103 which select desired printing pixels (bits).

Fig. 13 shows an example of the layout of the heater resistors 1101 and high-breakdown-voltage MOS transistors 1102 on the conventional heater board 1100 of the printhead.

Heater resistors 1101a1 to 1101ax, 1101b1 to 1101bx, ..., 1101m1 to 1101mx are connected to corresponding high-breakdown-voltage MOS transistors 1102a1 to 1102ax, 1102b1 to 1102bx, ..., 1102m1 to 1102mx.

In order to shorten the connection line between each heater resistor and a corresponding high-breakdown-voltage MOS transistor and effectively utilize the board area, the heater pitch as the heater resistor interval and the pitch of the high-breakdown-voltage MOS transistor which drives the heater are designed equal to each other.

Driving of the heater resistor has conventionally used a bipolar transistor. To cope with high density of heater resistors and low cost, the above-mentioned high-breakdown-voltage MOS transistor is being used.

For high-speed printing, it is desirable to

simultaneously drive nozzles (heater resistors) as many as possible. However, a simultaneously supplied current is restricted because of the limitation on the current supply ability of the power supply and a voltage drop by the 5 resistance of wiring from the power supply to a heater resistor.

For this reason, a plurality of heater resistors are driven by time division to discharge ink. For example, heater resistors are classified into a plurality of groups, 10 and driven by time division so as not to simultaneously drive two or more heater resistors within a group. This suppresses the total heater current, eliminating the need for supplying a large current at once.

Fig. 14 shows a heater resistor driving circuit for 15 discharging ink from each nozzle.

Reference numeral 1101 denotes each heater resistor; 1102, each high-breakdown-voltage MOS transistor; 1104, a power supply line which is connected to the power supply; and 1105, each control terminal which is connected to a 20 controller.

As shown in Fig. 14, the heater resistors 1101 and corresponding high-breakdown-voltage MOS transistors 1102 are classified into groups a to m in equal numbers.

More specifically, in group a, the power supply line 25 1104 is commonly connected to the heater resistors 1101a1 to 1101ax. The high-breakdown-voltage MOS transistors 1102a1 to 1102ax are series-connected to the corresponding

heater resistors 1101a1 to 1101ax between the power supply 1104 and ground.

When the bit selection circuit 1103 outputs control signals 1106a1 to 1106ax to the heater resistors 1101 via 5 the control terminals 1105, the switching circuits of the high-breakdown-voltage MOS transistors 1102a1 to 1102ax are turned on to supply a current from the power supply via the power supply line 1104 and heat the heater resistors 1101a1 to 1101ax.

10 The arrangements of groups b to m are also the same as that of group a.

The control signals 1106a1 to 1106ax from the bit selection circuit 1103 are input to the control terminals 1105 to control driving of the corresponding 15 high-breakdown-voltage MOS transistors 1102a1 to 1102ax. Since the heater resistors 1101a1 to 1101ax receive a voltage of 5 V or more, e.g., 16 to 24 V, the high-breakdown-voltage MOS transistors 1102a1 to 1102ax have a higher breakdown voltage than that of a general MOS transistor.

20 Fig. 15 is a timing chart showing the heater driving circuit in Fig. 14, i.e., a heater driving circuit for driving heater resistors belonging to each group.

Group a in Fig. 14 will be exemplified. The control signals 1106a1 to 1106ax are timing signals for driving the 25 first to xth heater resistors 1101a1 to 1101ax belonging to group a. That is, the control signal 1106 represents a waveform input to the control terminal 1105 of each

high-breakdown-voltage MOS transistor 1102 in group a. The high-breakdown-voltage MOS transistor 1102 is turned on (connected) for Hi and off (disconnected) for Lo. The remaining groups b to m operate similarly to group a.

5        In this manner, heaters in each group are sequentially driven by time division. The current in each group can always be controlled to a current of 1 bit (pixel printed by one nozzle) or less, and no large current need be supplied to heater resistors at once. Figs. 16A and 16B show the  
10      sectional structures of a high-breakdown-voltage MOS transistor and normal-breakdown-voltage MOS transistor.

Fig. 16B shows a normal-breakdown-voltage NMOS transistor formed on a P-type semiconductor substrate. N<sup>+</sup> diffusion layers 111 and 113 respectively form a source and  
15      drain, and a gate 112 is arranged between them.

Fig. 16A shows a high-breakdown-voltage NMOS transistor formed on a P-type semiconductor substrate. N<sup>+</sup> diffusion layers 111 and 113 of the high-breakdown-voltage MOS transistor respectively form a source and drain, and  
20      a gate 112 is arranged between them, similar to the normal-breakdown-voltage NMOS transistor.

In the high-breakdown-voltage MOS transistor, the gate length is larger than that in the normal MOS transistor, and an N<sup>-</sup> diffusion layer 114 for maintaining a uniform field  
25      is arranged between the gate 112 and the drain 113, which yields a high breakdown voltage.

In recent years, higher-speed, higher-resolution

printers are required, and the printhead of the printer is equipped with many nozzles at a high density. As for the arrangement of a heater board used for the printhead, it is necessary to increase the number of heaters (heater resistors) and decrease the pitch of heaters (heater resistors).

The heater board is constituted by forming a heater and driving circuit on a single semiconductor substrate. The number of heater boards formed from one wafer must be increased to reduce the cost. For this purpose, the heater board must be downsized.

However, an increase in heater density and downsizing of the heater board pose the following problems.

When the heater density is increased, the pitch of heater driving transistors is determined, and the unit area of the heater driving transistor decreases. As a result, the ON resistance of the transistor in driving the heater increases.

Also when the area of the driving circuit is decreased for downsizing the heater board, the transistor area decreases. The ON resistance of the transistor in driving the heater increases.

The heater and the transistor serving as a heater driving switch are series-connected to the power supply, as shown in Fig. 14. If the ON resistance of the transistor in driving the heater increases upon increasing the heater density or downsizing the heater board, power consumption

of the transistor increase and the ratio of power consumption of the heater to application power decreases, resulting in low power use efficiency.

If heat generation increases in the transistor,  
5 generated heat is accumulated in the transistor to change the ink discharge characteristic, or destructs the printhead.

To prevent this, it is important to decrease the ratio of the ON resistance of the transistor in driving the heater  
10 to the heater resistance when increasing the heater density or downsizing the heater board.

As a method of decreasing the ratio of the ON resistance of the transistor in driving the heater to the heater resistance, the heater resistance value is increased to  
15 relatively decrease the ratio of the ON resistance.

In the use of the method of relatively decreasing the ratio of the ON resistance, if heating amount of heater is not changed, the voltage applied to the heater must be increased. Along with this, the power supply voltage rises.

20 That is, if the power supply voltage rises, the voltage applied to the high-breakdown-voltage MOS transistor for driving a heater also rises. The breakdown voltage of the high-breakdown-voltage MOS transistor must be further increased.

25 To increase the breakdown voltage of the high-breakdown-voltage MOS transistor, the gate length or the length of the drift region must be increased. In either

measure, since the transistor area increases, it may be hard to downsize the heater board.

As described above, it is important to decrease the ON resistance of the transistor in driving the heater without 5 increasing the transistor area when increasing the heater density or downsizing the heater board.

#### SUMMARY OF THE INVENTION

The present invention has been made to overcome the 10 conventional drawbacks, and has as its object to provide a printhead capable of decreasing the ON resistance value without increasing the heater board size in order to downsize the heater board, an image printing apparatus using the printhead, and a control method therefor.

15 To achieve the above object, an image printing apparatus according one aspect of the present invention has the following arrangement. That is, an image printing apparatus which prints an image in accordance with input printing data by a printhead having a plurality of printing 20 elements comprises a plurality of individual switches which are arranged for the respective printing elements, a common switch which is arranged commonly to printing elements belonging to each of a plurality of groups of the printing elements, and driving means for controlling the plurality 25 of individual switches and the common switch and driving the printing elements in accordance with the input printing data, wherein the individual switch is formed from a MOS

transistor, and the common switch is formed from a high-breakdown-voltage MOS transistor having a higher breakdown voltage than a breakdown voltage of the MOS transistor for the individual switch.

5 For example, the printing elements, the plurality of individual switches, and the common switch may be arranged on a single semiconductor substrate.

For example, the MOS transistor for the individual switch and the high-breakdown-voltage MOS transistor may  
10 be series-connected.

For example, the MOS transistor for the individual switch and the high-breakdown-voltage MOS transistor may be formed from NMOS transistors.

For example, the printing element, the MOS transistor  
15 for the individual switch, and the high-breakdown-voltage MOS transistor for the common switch may be sequentially arranged into a circuit from a power supply line side to ground.

For example, the MOS transistor for the individual switch may include a PMOS transistor, the high-breakdown-voltage MOS transistor include an NMOS transistors, and the MOS transistor for the individual switch, the printing element, and the high-breakdown-voltage MOS transistor for the common switch  
25 be sequentially arranged into a circuit from a power supply line side to ground.

For example, the printhead may include a printhead

which discharges ink by using heat energy, and the image printing apparatus further comprise a thermal transducer for generating heat energy to be applied to ink.

To achieve the above object, a printhead according 5 another aspect of the present invention has the following arrangement. That is, a printhead which has a plurality of printing elements and is used in an image printing apparatus for printing an image in accordance with input printing data comprises a plurality of individual switches 10 which are arranged for the respective printing elements, a common switch which is arranged commonly to printing elements belonging to each of a plurality of groups of the printing elements, and signal reception means for, when receiving an individual switch operating signal for 15 operating the plurality of individual switches or a common switch operating signal for operating the common switch, inputting the received signal to the individual switch or the common switch, wherein the individual switch is formed from a MOS transistor, and the common switch is formed from 20 a high-breakdown-voltage MOS transistor having a higher breakdown voltage than a breakdown voltage of the MOS transistor for the individual switch.

For example, the printing elements, the plurality of individual switches, and the common switch may be arranged 25 on a single semiconductor substrate.

For example, the MOS transistor for the individual switch and the high-breakdown-voltage MOS transistor may

be formed from NMOS transistors.

For example, the printing element, the MOS transistor for the individual switch, and the high-breakdown-voltage MOS transistor for the common switch may be sequentially 5 arranged into a circuit from a power supply line side to ground.

For example, the MOS transistor for the individual switch may include a PMOS transistor, the high-breakdown-voltage MOS transistor include an NMOS 10 transistors, and the MOS transistor for the individual switch, the printing element, and the high-breakdown-voltage MOS transistor for the common switch be sequentially arranged into a circuit from a power supply line side to ground.

15 For example, the printhead may include a printhead which discharges ink by using heat energy, and further comprises a thermal transducer for generating heat energy to be applied to ink.

Other features and advantages of the present invention 20 will be apparent from the following description taken in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the figures thereof.

25 BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate

embodiments of the invention and, together with the description, serve to explain the principles of the invention.

5 Fig. 1 is a block diagram showing an example of the arrangement of a heater board according to an embodiment of the present invention;

Fig. 2 is a circuit diagram showing an example of the arrangement of a driving circuit according to the first embodiment of the present invention;

10 Fig. 3 is a timing chart for driving the driving circuit according to the first embodiment of the present invention;

Fig. 4 is a block diagram showing an example of the arrangement of a heater resistor, MOS transistor, and 15 high-breakdown-voltage MOS transistor on a heater board according to the first embodiment of the present invention;

Fig. 5 is a flow chart for explaining a driving circuit control method according to the present invention;

20 Fig. 6 is a circuit diagram showing an example of the arrangement of a heater resistor, MOS transistor, and high-breakdown-voltage MOS transistor on a heater board according to the second embodiment of the present invention;

Fig. 7 is a circuit diagram showing an example of the arrangement of a heater resistor, MOS transistor, and 25 high-breakdown-voltage MOS transistor on a heater board according to the third embodiment of the present invention;

Fig. 8 is a circuit diagram showing an example of the

arrangement of a heater resistor, MOS transistor, and high-breakdown-voltage MOS transistor on a heater board according to the fourth embodiment of the present invention;

5 Fig. 9 is a perspective view schematically showing the outer appearance of an ink-jet printer according to the embodiment of the present invention;

Fig. 10 is a block diagram showing the arrangement of an ink-jet printer control circuit according to the embodiment of the present invention;

10 Fig. 11 is a perspective view showing the outer appearance of an ink cartridge dividable into an ink tank and head according to the embodiment of the present invention;

15 Fig. 12 is a block diagram showing an example of the arrangement of a conventional heater board;

Fig. 13 is a block diagram showing an example of the arrangement of a heater resistor and high-breakdown-voltage MOS transistor on the conventional heater board;

20 Fig. 14 is a circuit diagram showing an example of the arrangement of a conventional driving circuit;

Fig. 15 is a timing chart for driving the conventional driving circuit;

Fig. 16A is a sectional view showing the sectional structure of a high-breakdown-voltage MOS transistor; and

25 Fig. 16B is a sectional view showing the sectional structure of a normal-breakdown-voltage MOS transistor.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will now be described in detail in accordance with the accompanying drawings. The following embodiments will 5 describe an ink-jet printhead, a serial ink-jet printer serving as an image printing apparatus having the printhead, and a control method therefor. However, the scope of the present invention is not limited to the described examples.

### [First Embodiment]

10 An ink-jet printer having an ink-jet printhead according to the first embodiment will be explained.

#### [General Description of Ink-Jet Printer]

Fig. 9 is a perspective view schematically showing the outer appearance of an ink-jet printer IJRA as a typical 15 ink-jet printer according to the embodiment of the present invention.

In Fig. 9, a pin (not shown) is attached to a carriage HC which engages with a helical groove 5004 of a lead screw 5005 that rotates via driving force transfer gears 5009 to 20 5011 while interlocking with forward/reverse rotation of a driving motor 5013. The carriage HC is supported by a guide rail 5003 and reciprocates in directions indicated by arrows a and b.

The carriage HC supports an integral ink-jet cartridge 25 IJC which incorporates a printhead IJH and ink tank IT.

Reference numeral 5002 denotes a sheet press plate which presses a printing sheet P against a platen 5000 in

the moving direction of the carriage HC.

Reference numerals 5007 and 5008 denote photocouplers serving as home position detectors for detecting the presence of a carriage lever 5006 in a corresponding region and 5 switching the rotational direction of the motor 5013.

Reference numeral 5016 denotes a member which supports a cap member 5022 that caps the front surface of the printhead IJH; and 5015, a suction unit which sucks the interior of the cap and performs suction recovery of the printhead via 10 an intra-cap opening 5023.

Reference numeral 5017 denotes a cleaning blade; and 5019, a member capable of moving this blade back and forth. The cleaning blade 5017 and member 5019 are supported by a main body support plate 5018. The blade is not limited 15 to this embodiment, and a known cleaning blade can be applied to the embodiment.

Reference numeral 5021 denotes a lever which starts suction for suction recovery, and moves together with movement of a cam 5020 engaged with the carriage. A driving 20 force from the driving motor is controlled by a known transfer mechanism such as a clutch switch.

Capping, cleaning, and suction recovery are executed by desired processes at corresponding positions by the operation of the lead screw 5005 when the carriage comes 25 to the home-position region. This embodiment can adopt any setting as long as desired operations are done at known timings.

[Description of Printing Control Arrangement]

A control arrangement which executes printing control of the ink-jet printer IJRA will be described.

Fig. 10 is a block diagram showing the arrangement 5 of a control circuit for the ink-jet printer IJRA. In Fig. 10, reference numeral 1700 denotes an interface which inputs a printing signal; 1701, an MPU; 1702, a ROM which stores a control program executed by the MPU 1701; and 1703, a DRAM which stores various data (printing signal, printing 10 data supplied to the head, and the like).

Reference numeral 1704 denotes a gate array (G.A.) which controls supply of printing data to the printhead IJH, and also controls data transfer between the interface 1700, the MPU 1701, and the RAM 1703.

15 Reference numeral 1710 denotes a carrier motor for conveying the printhead IJH; 1709, a convey motor for conveying a printing sheet; 1705, a head driver which drives the printhead; and 1706 and 1707, motor drivers for respectively driving the convey motor 1709 and carrier motor 20 1710.

The operation of the control arrangement will be explained. When a printing signal is input to the interface 1700, the printing signal is converted into printing data between the gate array 1704 and the MPU 1701. The motor 25 drivers 1706 and 1707 are driven, and the printhead is driven in accordance with the printing data sent to the head driver 1705 to print the data.

In this case, the control program executed by the MPU 1701 is stored in the ROM 1702. It is also possible to add an erasable/writable storage medium such as an EEPROM and change the control program from a host computer connected 5 to the ink-jet printer IJRA.

The ink tank IT and printhead IJH may be integrated into an exchangeable ink cartridge IJC, as described above. It is also possible to separately constitute the ink tank IT and printhead IJH, and when ink runs short, exchange only 10 the ink tank IT.

#### [Ink Cartridge]

Fig. 11 is a perspective view showing the outer appearance of the ink cartridge IJC dividable into the ink tank and head.

15 As shown in Fig. 11, the ink cartridge IJC can be divided into the ink tank IT and printhead IJH at a boundary K (black). The ink cartridge IJC has an electrode (not shown) for receiving an electrical signal supplied from the carriage HC when the ink cartridge IJC is mounted on the carriage 20 HC. The printhead IJH is driven by the electrical signal to discharge ink, as described above. In Fig. 11, reference numeral 500 denotes an ink orifice line. The ink tank IT has a fibrous or porous ink absorber in order to hold ink.

#### [Heater Driving Circuit of Printhead]

25 The printhead according to the first embodiment which is mounted in the above-described ink-jet printer will be explained.

Fig. 1 shows the layout of elements (circuits) on a heater board 100 for the printhead of the first embodiment.

The printhead heater board (element board) 100 comprises, on a single semiconductor substrate, heater resistors 101 serving as electrothermal transducers (printing elements), MOS transistors 102 which switch a predetermined current for the heater resistors 101, high-breakdown-voltage MOS transistors 103 which switch a current for respective groups surrounded by dotted lines in Fig. 2, bit selection circuits 104 which select desired printing pixels (bits), a data selection circuit 110, input pads 111, and a block selection circuit 112 which selects a heater in the group.

Fig. 2 shows a heater driving circuit 120 for discharging ink from the nozzle (orifice) of the printhead according to the first embodiment. The heater driving circuit 120 is divided into groups a to m.

In Fig. 2, reference numerals 101a1 to 101mx denote heater resistors (printing elements); 102a1 to 102mx, MOS transistors serving as individual switches which are arranged for the respective heater resistors and switch the heater resistors; 103a to 103m, high-breakdown-voltage MOS transistors which belong to groups a to m, serve as common switches arranged commonly to parallel-connected heater resistors, and have higher breakdown voltages than those of the MOS transistors 102a1 to 102mx; 105, a power supply line connected to a power supply (not shown); and 106a and

106b, control terminals connected to a controller (not shown).

In the first embodiment, the MOS transistor 102 (N type) having a lower ON resistance in driving the heater resistor than that of the high-breakdown-voltage MOS transistor is used as an individual switch arranged for each heater resistor, in order to decrease the ON resistance of the transistor in driving the heater resistor. The high-breakdown-voltage MOS transistor (N type) is used only as a common switch commonly arranged for heater resistors. Compared to the use of a high-breakdown-voltage MOS transistor as an individual switch, the heater board according to the first embodiment has a smaller number of high-breakdown-voltage MOS transistors used, and the ON resistance of the entire heater board in driving the heater resistor can be decreased. Since the heater resistor is connected to the power supply 105 and the transistor is arranged on the ground side, the ON resistance in driving the heater board is further decreased.

As shown in Fig. 2, the heater driving circuit 120 is divided into groups a to m. Groups a to m contain the same number of heater resistors 101 and the same number of MOS transistors 102 serving as heater resistor driving switches. Each of groups a to m contains one high-breakdown-voltage MOS transistor 103 serving as a driving switch for driving the heater resistor 101.

For example, in group a, the power supply line 105

is commonly connected to the heater resistors 101a1 to 101ax. The MOS transistors 102a1 to 102ax serving as the first driving switches of the heater resistors 101a1 to 101ax are series-connected between the power supply 105 and ground.

5 One high-breakdown-voltage MOS transistor serving as the second driving switch of the heater resistors 101a1 to 101ax is parallel-connected as a common switch between the MOS transistors 102a1 to 102ax and ground. Although not described, the remaining groups b to m have the same

10 arrangement as that of group a.

[Operation of Heater Driving Circuit]

The operation of the heater driving circuit 120 will be explained with reference to the waveform timing chart of Fig. 3.

15 Fig. 3 is a timing chart showing a driving signal for driving x heater resistors in respective groups when x heaters are classified into groups in units of m heaters.

Control signals 107a1 to 107ax in Fig. 3 are input to the control terminals 106a1 to 106ax to drive the MOS 20 transistors 102a1 to 102ax. The transistor is turned on (connected) for Hi in the waveform and off (disconnected) for Lo. A control signal 108 is input to the control terminals 106b in Fig. 2 to drive the high-breakdown-voltage MOS transistors 103a to 103m. The transistor is turned on 25 (connected) for Hi in the waveform and off (disconnected) for Lo.

The timing chart in Fig. 3 will be described by

exemplifying group a in Fig. 2. The control signals 107a1 to 107ax are driving timing signals for the MOS transistors 102a1 to 102ax serving as the first driving switches of the first to xth heater resistors 101 belonging to group a. The 5 control signal 108 is a driving timing signal for the high-breakdown-voltage MOS transistor 103a serving as the second driving switch of the first to xth heater resistors 101.

Application of a current to the first heater resistor 101a1 and stop of application will be explained. At time t1 in Fig. 3, the control signal 107a1 changes to Hi, and the MOS transistor 102a1 (first switch) of the heater resistor 101a1 is turned on.

At time t1, the high-breakdown-voltage MOS transistor 103a is OFF, and no current flows through the heater resistor 101a1.

At time t2, the control signal 108 changes to Hi, and the high-breakdown-voltage MOS transistor 103a (second switch) is turned on. A current is supplied to the heater resistor 101a1 connected to the MOS transistor 102a1 selected by the control signal 107a1.

Upon reception of the current, the heater resistor 101a1 is heated at an interval between time t2 and time t3. Heated ink is discharged from a nozzle, printing a 25 predetermined pixel (dot).

At time t3, the control signal 108 changes to Lo, the high-breakdown-voltage MOS transistor 103a (second switch)

is turned off, and application of a current to the heater resistor 101a1 stops.

At time t4, the control signal 107a1 changes to Lo, and the MOS transistor 102a1 is turned off.

5 Application of a current to the heater resistors 101a2 to 101ax, printing of predetermined pixels (dots) by discharging heated ink, and stop of applying a current to the heater resistors 101a2 to 101ax are sequentially performed in accordance with the timing chart of Fig. 3.

10 By sequentially driving heaters in the respective groups by time division, the current in each group can always be controlled to a current of 1 bit (pixel printed by one nozzle) or less. No large current need be supplied to heater resistors at once.

15 In this control, the current flowing through the heater resistor 101a1 is controlled in accordance with the control signal 108, and the pulse width of the current flowing through the heater resistor 101a1 is controlled by the high-breakdown-voltage MOS transistor 103a.

20 The heater resistors 101a1 to 101ax in group a are selected by selecting the MOS transistors 102a1 to 102ax. The pulse widths of the control signals 107a1 to 107ax for the MOS transistors 102a1 to 102ax are set large so as to contain corresponding parts of the control signal 108.

25 When the current flowing through the heater resistor changes from OFF to ON or from ON to OFF, a selected MOS transistor 102 is always ON (connected).

The MOS transistor 102 is not switched while the voltage between the source and the drain is high. Thus, a MOS transistor lower in breakdown voltage than the high-breakdown-voltage MOS transistor 103 can be adopted.

5 [Arrangement of Heater Board]

Fig. 4 shows an example of the layout of the heater resistors, MOS transistors, and high-breakdown-voltage MOS transistors on the heater board 100 according to the first embodiment. The heater resistors 101a1 to 101mx are 10 series-connected to the corresponding MOS transistors 102a1 to 102mx.

The pitch of the heater resistors 101a1 to 101mx and the pitch of the corresponding MOS transistors 102a1 to 102mx are set equal to each other in order to shorten the connection 15 line and effectively utilize the board area. Each of the high-breakdown-voltage MOS transistors 103a to 103m is arranged in a corresponding group, and designed to a length set by multiplying the number (x) of heater resistors in each group by the pitch of the heater resistors. The 20 high-breakdown-voltage MOS transistors 103a to 103m are arranged at positions shown in Fig. 4 so as to be connected to the corresponding MOS transistors 102a1 to 102ax, 102b1 to 102bx, . . . in the respective groups.

The high-breakdown-voltage MOS transistors 103a to 25 103m have a higher ON resistance per unit area than that of the general MOS transistors 102a1 to 102mx. As shown in Fig. 4, the areas of the high-breakdown-voltage MOS

transistors 103a to 103m are set larger than those of the general MOS transistors 102a1 to 102mx. This can satisfactorily decrease the ON resistances of the high-breakdown-voltage MOS transistors 103a to 103m.

5        The normal-breakdown-voltage MOS transistors 102a1 to 102mx which are lower in ON resistance value per unit area are employed as transistors which select heater resistors in each group. The sum of the ON resistances of the MOS transistors 102a1 to 102mx series-connected to heater  
10      resistors and the high-breakdown-voltage MOS transistors 103a to 103m can be suppressed small.

15      The switching MOS transistors and high-breakdown-voltage MOS transistors for controlling a voltage applied to heater resistors are integrally formed together with the heater resistors in a common substrate by a semiconductor process. The line between MOS transistors and the line up to an orifice heater with voltage variations can be shortened, improving the response performance of the circuit.

20      [Operation of Heater Driving Circuit]

The operation of the heater driving circuit 120 will be explained with reference to the flow chart of Fig. 5.

25      In step S100, the control signals 107a1 to 107ax and control signal 108 in Fig. 3 are received. The control signals 107a1 to 107ax are driving timing signals (first control signals) for the MOS transistors 102a1 to 102ax serving as the first driving switches of the first to xth

heater resistors 101a1 to 101ax belonging to group a. The control signal 108 is a driving timing signal (second control signal) for the high-breakdown-voltage MOS transistor 103a serving as the second driving switch of the first to xth heater resistors 101a1 to 101ax.

5 In step S110, whether the first control signal is "Hi" is determined. If NO in step S110, the flow waits until the first control signal changes to "Hi"; if YES, advances to step S120.

10 In step S120, the control signal 107a1 changes to "Hi" at time t1 in Fig. 3, and the MOS transistor 102a1 (first switch) of the heater resistor 101a1 is turned on. At time t1, the high-breakdown-voltage MOS transistor 103a is OFF, and no current flows through the heater resistor 101a1.

15 In step S130, whether the second control signal is "Hi" is determined. If NO in step S130, the flow waits until the second control signal changes to "Hi"; if YES, advances to step S140.

20 In step S140, the control signal 108 changes to "Hi" at time t2 in Fig. 3, and the high-breakdown-voltage MOS transistor 103a (second switch) is turned on.

In step S150, a current is supplied to the heater resistor 101a1 connected to the MOS transistor 102a1 selected by the control signal 107a1. The current heats the heater resistor 101a1 at an interval between time t2 and time t3, and heated ink is discharged from the nozzle to print a predetermined pixel (dot).

The flow advances to step S160 to determine whether the second control signal is "Lo". If NO in step S160, the flow waits until the second control signal changes to "Lo"; if YES, advances to step S170.

5 In step S170, the control signal 108 changes to "Lo" at time t3 in Fig. 3, and the high-breakdown-voltage MOS transistor 103a (second switch) is turned off.

In step S180, current supply to the heater resistor 101a1 stops.

10 The flow advances to step S190 to determine whether the first control signal is "Lo". If NO in step S190, the flow waits until the first control signal changes to "Lo"; if YES, advances to step S200.

In step S200, the control signal 107a1 changes to "Lo" 15 at time t4 in Fig. 3, and the MOS transistor 102a1 is turned off. The flow advances to step S210 to end a series of processes.

#### [Second Embodiment]

An ink-jet printhead according to the second 20 embodiment and an ink-jet printer having the printhead will be described.

The ink-jet printer having the ink-jet printhead according to the second embodiment can take the same arrangement as that of the ink-jet printer described in the 25 first embodiment. A repetitive description of the ink-jet printer and its control method will be omitted.

#### [Heater Driving Circuit of Printhead]

The printhead according to the second embodiment which is mounted in the ink-jet printer will be explained.

Fig. 6 shows a heater driving circuit 220 for discharging ink from the nozzle of the printhead according 5 to the second embodiment.

In Fig. 6, reference numerals 201a1 to 201mx denote heater resistors; 202a1 to 202mx, MOS transistors; 203a to 203m, high-breakdown-voltage MOS transistors; 204, a power supply line connected to a power supply (not shown); and 10 205 and 206, control terminals connected to a controller (not shown).

As shown in Fig. 6, the heater driving circuit 220 is divided into groups a to m. Groups a to m contain the same number of heater resistors 201 and the same number of 15 MOS transistors 202 serving as heater resistor driving switches. Groups a to m contain the corresponding high-breakdown-voltage MOS transistors 203a to 203m serving as driving switches for driving the heater resistors 201 in the respective groups.

20 The second embodiment is different from the first embodiment in that the switching MOS transistor which selects and drives a heater resistor in a group is a P-type MOS transistor higher in breakdown voltage than an N-type MOS transistor, instead of an N-type MOS transistor used in the 25 first embodiment.

This arrangement can increase the breakdown voltage of the switching MOS transistor for a printhead in which

switching MOS transistors are arranged at a high density.

[Third Embodiment]

An ink-jet printhead according to the third embodiment and an ink-jet printer having the printhead will be 5 described.

The ink-jet printer having the ink-jet printhead according to the third embodiment can take the same arrangement as that of the ink-jet printer described in the first embodiment. A repetitive description of the ink-jet 10 printer and its control method will be omitted.

[Heater Driving Circuit of Printhead]

The printhead according to the third embodiment which is mounted in the ink-jet printer will be explained.

Fig. 7 shows a heater driving circuit 320 for 15 discharging ink from the nozzle of the printhead according to the third embodiment.

In Fig. 7, reference numerals 301a1 to 301mx denote heater resistors; 302a1 to 302mx, MOS transistors; 303a to 303m, high-breakdown-voltage MOS transistors; 304, a power 20 supply line connected to a power supply (not shown); and 305 and 306, control terminals connected to a controller (not shown).

As shown in Fig. 7, the heater driving circuit 320 is divided into groups a to m. Groups a to m contain the 25 same number of heater resistors 301 and the same number of MOS transistors 302 serving as heater resistor driving switches. Groups a to m contain the corresponding

high-breakdown-voltage MOS transistors 303a to 303m serving as driving switches for driving the heater resistors 301 in the respective groups.

The third embodiment is different from the first 5 embodiment in that the MOS transistor (individual switch) which selects and drives a heater resistor in a group is a P-type MOS transistor higher in breakdown voltage than an N-type MOS transistor, instead of an N-type MOS transistor used in the first embodiment, and the MOS transistor which 10 selects and drives a group is a P-type high-breakdown-voltage MOS transistor higher in breakdown voltage than an N-type MOS transistor, instead of an N-type high-breakdown-voltage MOS transistor (common switch) used in the first embodiment  
[Fourth Embodiment]

15 An ink-jet printhead according to the fourth embodiment and an ink-jet printer having the printhead will be described.

The ink-jet printer having the ink-jet printhead according to the fourth embodiment can take the same 20 arrangement as that of the ink-jet printer described in the first embodiment. A repetitive description of the ink-jet printer and its control method will be omitted.

[Heater Driving Circuit of Printhead]

The printhead according to the fourth embodiment which 25 is mounted in the ink-jet printer will be explained.

Fig. 8 shows a heater driving circuit 420 for discharging ink from the nozzle of the printhead according

to the fourth embodiment.

In Fig. 8, reference numerals 401a1 to 401mx denote heater resistors; 402a1 to 402mx, MOS transistors; 403a to 403m, high-breakdown-voltage MOS transistors; 404, a power supply line connected to a power supply (not shown); and 405 and 406, control terminals connected to a controller (not shown).

As shown in Fig. 8, the heater driving circuit 420 is divided into groups a to m. Groups a to m contain the same number of heater resistors 401 and the same number of MOS transistors 402 serving as heater resistor driving switches. Groups a to m contain the corresponding high-breakdown-voltage MOS transistors 403a to 403m serving as driving switches for driving the heater resistors 401 in the respective groups.

The fourth embodiment is different from the third embodiment in the layout of heater resistors in each group and the MOS transistor (individual switch) which selects and drives a heater resistor, and the use of an N-type MOS transistor as the MOS transistor. In the above embodiments, droplets discharged from the printhead are ink, and a liquid contained in the ink tank is ink. The content of the ink tank is not limited to ink. For example, the ink tank may contain a processing solution to be discharged onto a printing medium in order to increase the fixing properties, water resistance, or quality of a printed image.

Of ink-jet printing systems, the embodiments can adopt

a system which comprises a means (e.g., an electrothermal transducer) for generating heat energy as energy utilized to discharge ink and changes the ink state by heat energy. This ink-jet printing system can increase the printing 5 density and resolution.

As a representative arrangement or principle, the present invention preferably adopts the basic principle disclosed in, e.g., U.S. Patent No. 4,723,129 or 4,740,796. This system is applicable to both a so-called on-demand 10 apparatus and continuous apparatus. The system is particularly effective for the on-demand apparatus because of the following reason. At least one driving signal which corresponds to printing information and gives a rapid temperature rise exceeding nuclear boiling is applied to 15 an electrothermal transducer which is arranged in correspondence with a sheet or liquid channel holding a liquid (ink). This signal causes the electrothermal transducer to generate heat, and causes film boiling on the heat effecting surface of the printhead. Consequently, a 20 bubble can be formed in the liquid (ink) in one-to-one correspondence with the driving signal.

Growth and shrinkage of the bubble discharge the liquid (ink) from an orifice, forming at least one droplet. The driving signal more preferably has a pulse shape because 25 a bubble grows and shrinks instantaneously appropriately. This achieves discharge of the liquid (ink) with high response.

The pulse-like driving signal is preferably a signal disclosed in U.S. Patent No. 4,463,359 or 4,345,262. Conditions disclosed in U.S. Patent No. 4,313,124 which is an invention concerning the temperature rise ratio of the 5 heat effecting surface can provide higher-quality printing.

The printhead structure can be a combination (linear liquid channel or right-angle liquid channel) of orifices and electrothermal transducers (orifice heaters) which are arranged in correspondence with liquid channels. The 10 present invention also includes structures disclosed in U.S. Patent Nos. 4,558,333 and 4,459,600 in which the heat effecting surface of an orifice heater is arranged in a bent region.

A full line type printhead having a length 15 corresponding to the width of the largest printing medium printable by the printing apparatus can take a structure which meets this length by a combination of printheads as disclosed in the above-mentioned specifications, or a single integrated printhead structure.

20 It is also possible to employ a cartridge type printhead described in the embodiments in which an ink tank is integrated with a printhead itself, or an interchangeable chip type printhead which can be electrically connected to an apparatus main body and receive ink from the apparatus 25 main body when attached to the apparatus main body.

The printing mode of the printing apparatus is not limited to a printing mode using only a main color such as

black. The apparatus can adopt at least either a composite color mode using different colors or a full color mode using a color mixture regardless of whether the printhead is an integral printhead or a combination of printheads.

5 As described above, according to the embodiments, heater resistors are series-connected to normal MOS transistors in each group on a heater board. The pitch of the heater resistors and the pitch of the normal MOS transistors are designed equal to each other in order to

10 shorten the connection line. One high-breakdown-voltage MOS transistor is arranged in each group, and the pitch is designed to a length corresponding to the product of the pitch of the heater resistors and the number  $x$  of heater resistors. The high-breakdown-voltage MOS transistor has

15 a higher ON resistance value per unit area than that of the normal MOS transistor. However, the area of the high-breakdown-voltage MOS transistor is larger by  $x$  times than that of the normal MOS transistor. This can suppress the ON resistance of the high-breakdown-voltage MOS

20 transistor satisfactorily low.

Driving elements (high-breakdown-voltage MOS transistors) which classify heater resistors into a plurality of groups, and select and drive each group, and driving elements (normal MOS transistors) which select and

25 drive heaters in each group are formed on a single semiconductor substrate. The ON resistance of the driving element which drives a heater resistor can be decreased.

The area of the heater driving circuit can be reduced without changing the semiconductor manufacturing process.

As has been described above, the present invention can provide a printhead capable of decreasing the ON 5 resistance value without increasing the heater board size in order to downsize the heater board, an image printing apparatus using the printhead, and a control method therefor.

As many apparently widely different embodiments of the present invention can be made without departing from 10 the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments thereof except as defined in the claims.